Chapter 5.2

A synthesis of sediment chemical contaminant studies in the Maryland Coastal Bays

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Abstract

Sediment contaminants, especially metals and organics, are serious threats to estuarine ecosystems worldwide. This chapter summarizes sediment contaminant studies that have been conducted in the Coastal Bays, most within the last decade. EPA 1993 data indicated that overall sediment contaminants were decreasing throughout the Coastal Bays. However, this study was biased toward upper tributaries and dead-end canals, where contaminants were expected to be high. The National Coastal Assessment 2000 study was the most comprehensive to date, indicating that sediment contamination levels were low throughout the southern and open water northern Bays. Higher contaminant levels were restricted to localized areas in tributaries in the northern bays and in Newport Creek.

Introduction

Sediment contaminants**,** metals and organics, in sediments have been identified as a serious environmental problem in estuaries around the world. Contaminants are introduced into the Coastal Bays from run-off, direct discharge, and atmospheric deposition. While metals are found naturally in the near marine and marine environment, enrichment over background levels of certain trace metals can be attributed to human activities (Table 5.2.1). Organic contaminants, which include, but are not limited to, pesticides, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons, (PAHs) come from anthropogenic sources.

Most contaminants tend to bind onto fine-grained particles that eventually settle to the bottom of the bays. In low energy areas (e.g. dead-end canals) contaminants bind to sediments close to where they were introduced into the environment. Once in the sediments, the contaminants can have an adverse effect on the benthic organisms living in the sediments, resulting in lower biodiversity and/or abundance if contaminant concentrations are high enough. Even in trace or very low concentrations, benthic organisms can ingest the contaminants, accumulate the toxins in their tissue, and result in concentrations higher than those in the surrounding sediments. Additionally, contaminants may become more concentrated as they are work their way up the food chain (bioaccumulation).

Several approaches have been developed to assess the levels of sediment contaminants in terms of their potential toxicity to the benthic and fish community. Most approaches calculated threshold values of individual contaminants based on observed toxic effects on sensitive benthic animals. Long et al. (1995) determined two criterion limits, the Effects Range-Low (ERL) and the Effects Range Median (ERM) for 41 contaminants (including 9 metals, 13 PAHs, total PCBs and 10 other organic contaminants) based on correlative analyses of existing laboratory toxicity data, field studies and model data. They defined ERL values and ERM values as those concentrations above which adverse biological effects were seen in 10% and 50%, respectively, of the data reviewed. Another criterion limit is the Apparent Effects Threshold (AET) values derived from a correlation of the weight of evidence from multiple matched chemical and biological effects data sets (laboratory toxicity testing on field sediment samples). The AET value for a particular contaminant is defined as the sediment concentration above which an adverse biological effect is always statistically observed (U.S. EPA, 1992). AET values are available for 19 elements and 50 organic compounds (Buchman, 1999). AET threshold values for most of the contaminants fall between ERL and ERM values (Table 5.2.2).

Table 5.2.1: Sources of major toxic chemicals in the Coastal Bays.

Toxic Chemical or Chemicals	***Type of Toxic Chemical***	***Primary Uses or Sources***	***Comments***
DDT, DDE, DDD	Chlorinated Hydrocarbon	Insecticides and their breakdown products	Banned in the USA.
Chlordane	Chlorinated Hydrocarbon	Mix of several chlorinated insecticides	Use on crops banned in USA in the 1970s. Use for termite control stopped in 1980s.
PAH	Polycyclic Hromatic Hydrocarbon	Oil spills, by-products of combustion, creosotes, tars, natural sources	Naturally occurring substances but abundance has been greatly increased by human activity.
PCBs	Polychlorinated Biphenyls	Used in electrical transformers and capacitors	Banned for use in new equipment in the 1970s. Still found in some older equipment.
Tributyl tin, dibutyl tin, monobutyl tin	Organo-metallic Compounds	Antifouling paints and their breakdown products	Banned for use on vessels under 70 feet long.
Copper	Metal	Antifouling paints, wood preservatives, auto part wear, insecticides, plumbing	
Arsenic	Metal	Wood preservatives, pesticides	
Nickel	Metal	Paints and finishes	
Zinc	Metal	Galvanized metals, sacrificial anodes to prevent corrosion of metals in seawater, pigments in paints	
Lead	Metal	Paints, leaded fuels, batteries, plumbing	Use in auto fuels banned, sharply reducing releases.
Chromium	Metal	Chrome plating of metals	
Cadmium	Metal	Batteries, paints, pesticides	

The presence of multiple toxins in the environment is unclear but is thought to work simultaneously and compound the stress of any individual toxin on aquatic organisms. Long and others (1998) used mean ERM quotients as a technique to rank potential toxicity of sediments containing multiple contaminants. They found that as the mean ERM quotients increased, the incidence of toxic responses increased. The mean ERM quotient is calculated as the average of individual quotients obtained by dividing the concentration of each chemical contaminant by their respective ERM value. For the MCBP State of the Bay Report, mean AET quotient is used as the indicator to quantify potential sediment toxicity. Quotients based on AET threshold values are used primarily because ERM threshold values are not available for pesticides other than DDT.

Data Sets

USACE 1997 – West O.C. Fishing Harbor sediments tested for chemical and particle size.

CZM/MGS Sediment mapping report (Wells and others, 1999): metals, sediments collected between 1991 and 1996 (total of >900 sites);

EPA EMAP – Joint Assessment (Chaillou and others, 1996: metal and organic contaminants, sediments collected in 1993) – 13 sites analyzed for contaminants in MD.

EPA MAIA 1997-98 data – 25 sites analyzed for sediment contaminants, however, no sites were in northern two bays (north of Ocean City Inlet).

EPA National Coastal Assessment Program (NCA): sediments collected in 2000 and 2001 at 54 stations throughout the Coastal Bays.

Management Objective: none.

Draft Indicators
ERLs, ERMs, AETs (NOAA SQRT Tables), mean AET quotient

CRITERIA:
Trace metals: establish baseline data (MGS) and compare with more recent data sets noting any significant differences; ERM quotient (both metals and organics)
Organic contaminants: number of sediment contaminants exceeding ERL, ERM threshold values; change in AET quotient (based on both metals and organics)

Indicator 1: ER-L and ER-M values
Indicator 2: Apparent Effects Threshold Quotient

Results
Historical Data
Most of the information on sediment contaminants in Maryland's Coastal Bays has come from studies conducted within the last ten years. Between 1991 and 1995, the Maryland Geological Survey conducted an intensive sediment sampling in the Maryland Coastal Bays, collecting over

900 surficial sediment samples (Wells and Conkwright, 1999). They analyzed the sediments for total carbon, nitrogen and phosphorus and seven metals (cadmium, chromium, copper, iron, manganese, nickel, lead, and zinc). They found that generally the bottom sediments in the Maryland's Coastal Bays did not contain excessively high concentrations of metals. While none of the samples contained metal concentrations exceeding the ERM values, sediments collected in St. Martin River, near marinas and along developed shorelines showed elevated level above background (historical) levels of copper and zinc.

In 1993, the Coastal Bays Joint Assessment (CBJA) collected water and sediment samples in an effort to characterized the Maryland and Delaware Coastal Bays (Chaillou et al., 1996). Because of budget constraints, CBJA analyzed sediment from 36 of the 200 sites sampled, and of those 36, only 16 were in Maryland's Coastal Bays (Figure 5.2.1). The sediments were analyzed for 15 elements, and 66 organic toxins. Chaillou and others (1996) noted that the number of contaminants exceeding the ERL limits increased from south to north. In Maryland, all but three samples contained one or more contaminants exceeding ERL values. Total chlordane concentrations exceeded ERL values in all but one sample. Arsenic and total DDT concentrations exceeded ERL values in half of the samples. The samples containing the most contaminants exceeding ERLs were collected in a dead-end canal in Assawoman Bay and in Trappe Creek. The sediment collected in the dead-end canal in Assawoman Bay was the only sample to contain a contaminant (Benz(a)anthracene) exceeding the ERM level. The authors concluded that the chlorinated hydrocarbons, the primary sediment contaminants detected, are remnants from historic inputs.

In 1997, EPA collected water and sediment samples in four estuarine systems in the mid-Atltantic region (USEPA, 2002). Data for Maryland Coastal Bays included 16 samples taken in lower bays (Sinepuxent, Newport, and Chincoteague Bays) and did not include the northern bays (Assawoman and Isle of Wight Bays). EPA ranked Chincoteague and Sinepuxent Bays as "good", meaning less than 20% of bay area have impaired values for organic contaminants in the sediments. Sinepuxent Bay was ranked as "good" with regard to metal contaminants in the sediments while 20% to 40% of Chincoteague Bay showed some impairment from metal contamination (USEPA 2002).

National Coastal Assessment

In 2000, as part of the National Coastal Assessment (NCA), EPA collected surficial sediments at 54 locations matching the water quality stations monitored for the Maryland Coastal Bays Program (Figure 5.2.2). The sediments were analyzed for water, mud (silt-clay), and total organic carbon content, 15 metals, 22 PAHs, 20 PCBs, and 20 pesticides. Table 5.2.2 lists the individual chemicals and the frequency at which they were detected (i.e., number of non-zero values reported). Many of the concentrations reported were less than the minimum detection limits (MDL). It is assumed that the laboratory responsible for the analyses reported a concentration value if the signal for the contaminant could be quantified. In this discussion, reported concentration value less than the given MDL are treated as real values.

Metal And Organic Contaminants

Although two metals, antimony (Sb) and silver (Ag), were detected in most of the samples, none of the reported concentrations were above the MDL. Likewise, none of the concentrations reported for pesticides Aldrin, Heptachlor, Lindane, Mirex, and O,P'DDD, and PCB congeners 126, 170, 18, 195, 206, and 77 were above the MDL. None of the sediment samples contained detectable levels of the pesticides Endrin or Toxaphene.

Correlation analyses were performed on the textural and chemical data from sediment analyses to determine what, if any, associations the contaminant may have with each other and with sediment texture (Table 5.2.3). All reported non-zero concentration values were included in the analyses. Except for mercury (Hg) and cadmium (Cd), correlations between almost all of the metals are significant at the 95% level (p-values < 0.05). Most of these correlations are very strong ($r > 0.7$). In addition, all metals show a strong association with water and silt-clay contents. Metals typically are associated with clay minerals as they are components of the mineral lattice structure or absorbed onto clay surfaces (Cantillo, 1982). Clay minerals comprise a significantly large portion of the fine (clay-size) sediment fractions.

Correlation analyses included organic contaminants groups (i.e., total PAH, DDT, PCB) instead of individual contaminants. Total DDT, total PCB and total DDT were obtained by summing the concentrations (including values below the MSD) of the individual contaminants in the respective chemical group. Total DDT and total PCB are significantly correlated with water and silt-clay content and most metals. Total PAH, on the other hand, shows little or no significant correlation with any of the other variables, suggesting that the PAH levels are not associated with a particular sediment type and/or levels are near the detection limit.

Thirty-three of the 54 samples contained at least one contaminant exceeding ERL threshold values (Table 5.2.4). Samples collected in West Ocean City harbor (MD-CB-01) and Newport Creek (MD-CB-33) contained 12 contaminants exceeding ERL values (including As, Cu, Ni, Zn, Acenaphthylene, Anthracene , Benzo(A)Anthracene, Chrysene, Fluoranthene, Fluorene, total PAHs, total DDTs). Samples collected in the St. Martin River, Bishopville Prong, Shingle Landing contained five contaminants exceeding ERL values. Sediments collected in Sinepuxent Bay and Chincoteague Bay generally had no more than two contaminants exceeding ERL values. Metals account for the majority of contaminants exceeding ERL (and AET) limits. Nickel (Ni) and arsenic (As) were the contaminants most often exceeding their ERL values, followed by zinc (Zn) and copper (Cu). The ERL values for Cu, Ni, and Zn, and AET value for Mn are at levels designated as 'background levels' found in the Maryland Coastal Bays (Wells and Conkwright 1999). The organic contaminant most often exceeding ERL value is total DDT.

None of the sediments contained contaminants exceeding their respective ERM threshold limits.

More than half the sediment samples contained at least one contaminant exceeding the AET limit. However, the maximum number of contaminants exceeding the AET limit was 3 (Site MD-CB-29 collected in St. Martin River). Like ERLs, metals account for the majority of contaminants exceeding AET limits. Most other samples contained one or two metal contaminants that exceeded AET, with manganese (Mn) being most frequent followed by chromium (Cr). The AETs reported for these metals are based on polychaete (*Neanthes*) bioassays and both values are lower than the respective ERL threshold limits (Buchman, 1999). However, the AET values for these metals are equal to background levels within the study, which demonstrates a limitation of using the sediment quality guideline (SQG) values.

Mean quotients based on AET limits (AET-Q) were calculated for each sediment sample collected in 2000 (Table 5.2.4). Although AET values are available for total chlordane, a persistent pesticide, the 2000 data did not report total chlordane values. Therefore, mean AET-Q does not account for chlordane. AET-Q is used to indicate "degree" of potential sediment toxicity based on multiple contaminant concentrations. AET-Q values range from 0.01 to 0.34 and directly related to the total organic carbon in the sediment (Figure 5.2.3). Higher values for AET-Q are associated with organic rich sediments collected in the tributaries to the northern bays (Figure 5.2.2).

Summary

<u>Comparison with Previous Studies</u>

The NCA 2000 data set represents the most comprehensive surficial sediment contaminant assessment yet. Cursory comparison with earlier data set such as EMAP93 data (Chaillou and others, 1996) suggests that the overall sediment contaminants have decreased over the past 11 years. However, caution should be exercised when making this comparison. The 1993 data set was limited in coverage and biased toward the more contaminated areas such as dead-end canals and upper tributaries. In addition, EPA1993 data reported total chlordane concentrations, which exceeded ERL limits in all but one sample. The NCA 2000 data did not report total chlordane. In addition, the 1993 data set contained some inconsistencies that cannot easily be explained. For example, the sandy sediment collected in mid-Chincoteague Bay (Site 714) contained the highest concentration of heptachlor, approximately 10 times that reported for other samples. Figure 5.2.1 shows the distribution of AET-Q based on EPA1993 data. AET-Qs were calculated in the same manner as those for the NCA 2000 data and do not include total chlordane.

<u>Conclusion</u>

Based on the NCA 2000 contaminant data, bottom sediments in Maryland southern Coastal Bays (Sinepuxent, Newport, and Chincoteague Bays) and open water area in Assawoman and Isle of Wight Bays do not contain high levels of contaminants. Generally, concentrations for most metal are within background levels. Most organic contaminants are at trace levels or below detection limits.

Higher contaminant levels were restricted to localized areas in tributaries in the northern bays and in Newport Creek. These areas were also high in total organic carbon.

Comparison with historical data suggests that sediment contaminants, particularly organic contaminants, may be decreasing. However, the historical data are not comparable in coverage. The 1993 data set (Chaillou et al, 1996) was biased toward the more contaminated areas such as dead-end canals, and the 1997 data set (USEPA 2002) did not include the northern Coastal Bays.

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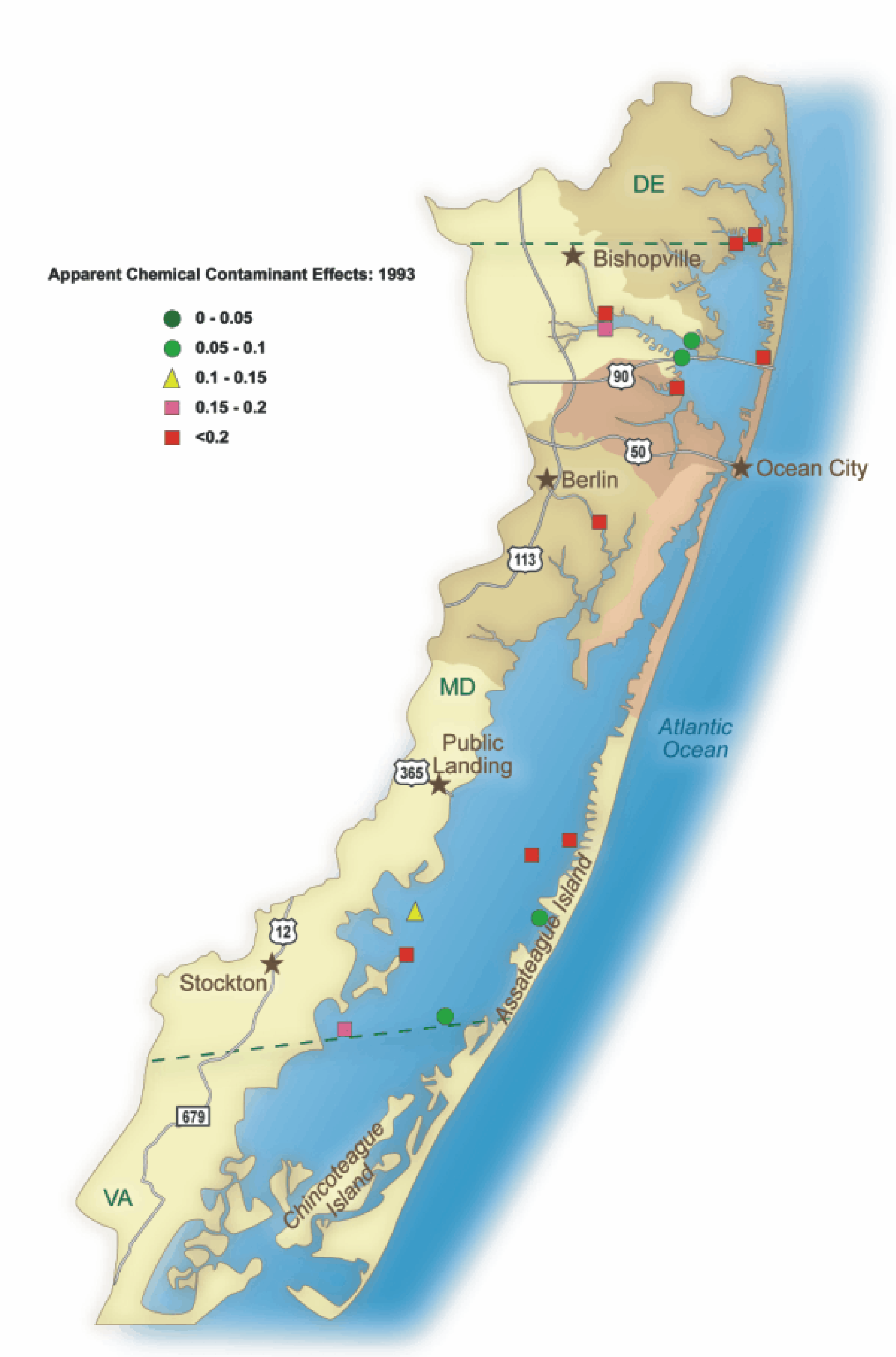

Figure 5.2.1: Map of sediment toxicity based on mean Apparent Effects Threshold (AET) values for samples collected by the Coastal Bays Joint Assessment in1993.

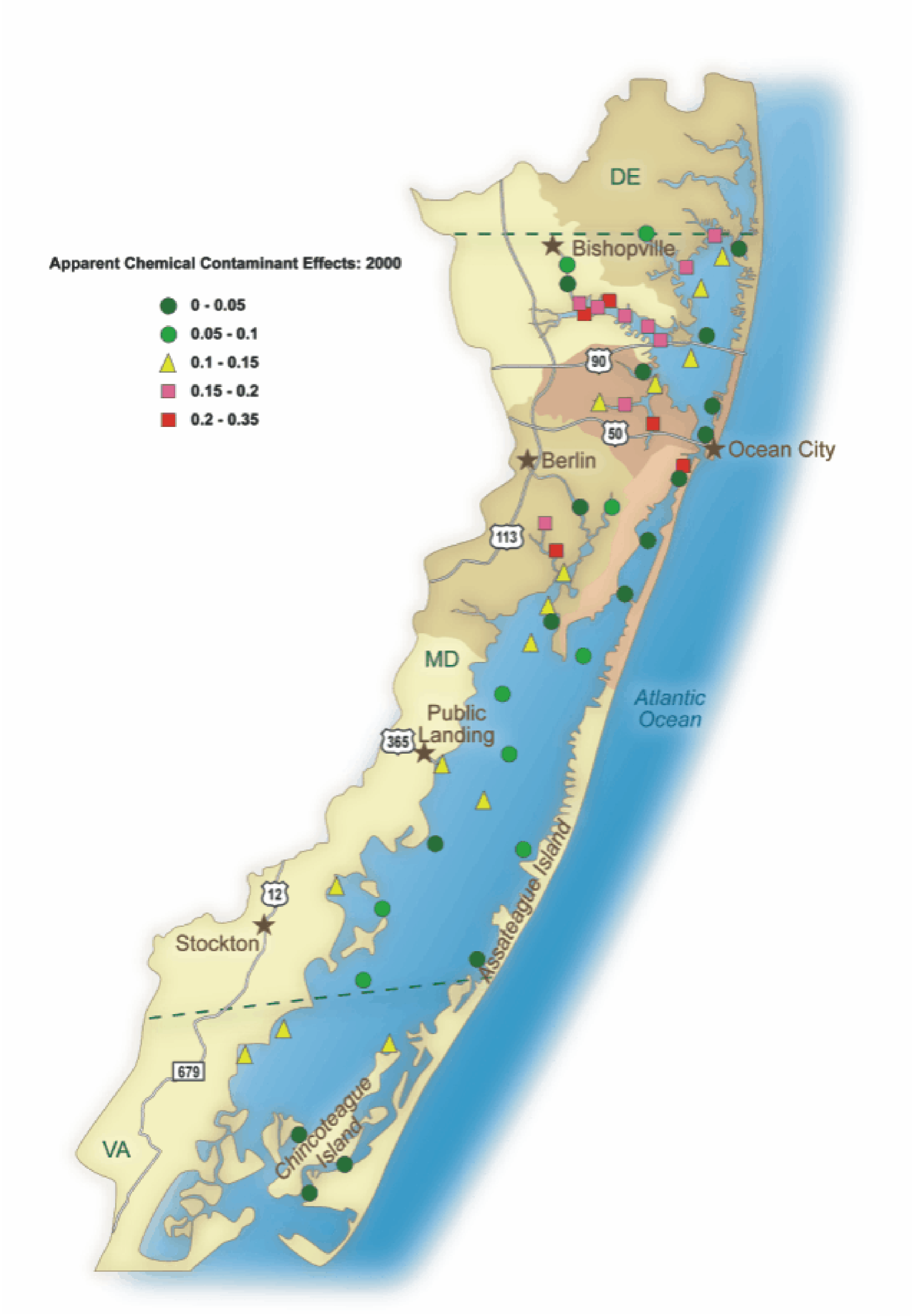

Figure 5.2.2: Map of sediment toxicity based on mean Apparent Effects Threshold (AET) values for samples collected by the Environmental Protection Agency in 2000.

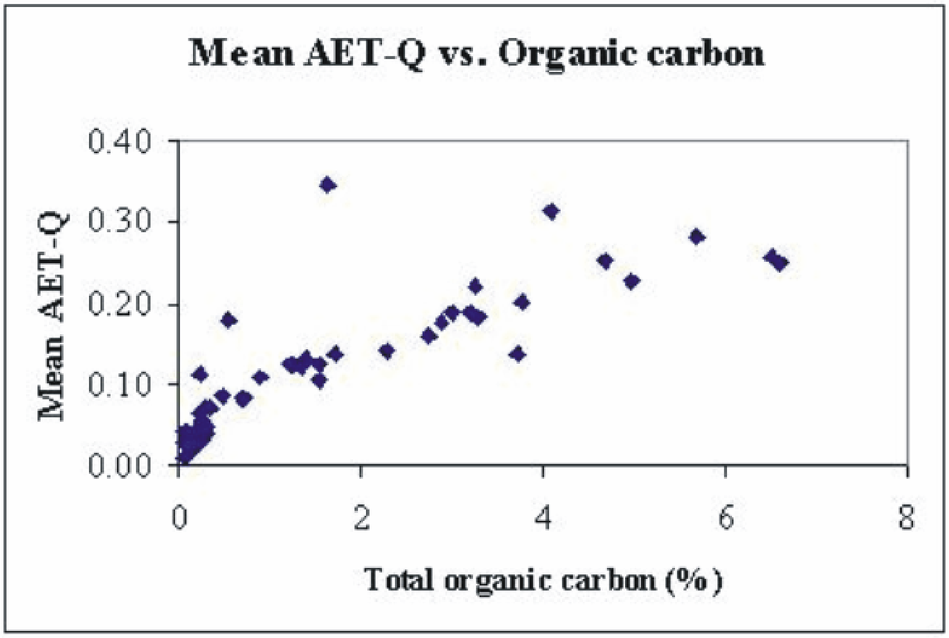

Figure 5.2.3: Plot showing the relationship between total organic carbon and mean AET-Q. The single outlier data point (AET-Q=0.34) corresponds to sediment collected in West Ocean City Harbor (see map- Figure 5.2.1; point nearest Ocean City).

Table 5.2.2: Listing of the chemical contaminants analyzed in the 54 sediment samples collected in 2000 for MCBP. The minimum detection limit for each chemical is listed along with the number of samples for which values were reported (indicating detection) and exceeded MDL. Also listed are the sediment quality guideline (SQG) values for each chemical, if available, and how many times the reported values exceeded those guidelines. Total PAHs, PCBs and DDTs were calculated as the sum of the concentration reported for the individual chemicals for each group.

Chemical Name	Abbreviation	Minimum Detection Limit (MDL)	Frequency of concentration		Sediment Quality Guideline Values			Frequency of reported concentrations exceeded SQG values		
			Reported (detected)	Exceeded MDL	ERL	ERM	AET	> ERL	> ERM	> AET
METALS										
ALUMINUM	AL	0.1	54	54						
ANTIMONY	SB	0.5	44	0	2	25	9.3	0	0	0
ARSENIC	AS	5	48	27	8.5	70	35	17	0	0
CADMIUM	CD	0.5	50	7	1.2	9.6	3	1	0	0
CHROMIUM	CR	5	54	49	81	370	62	0	0	9
COPPER	CU	5	54	38	34	270	390	7	0	0
IRON	FE	2	54	54						
LEAD	PB	0.5	54	54	46.7	218	400	0	0	0
MANGANESE	MN	5	54	54			260			28
MERCURY	HG	0.02	40	33	0.15	0.71	0.41	0	0	0
NICKEL	NI	5	54	38	20.9	51.6	110	26	0	0
SELENIUM	SE	0.1	42	34			1			1
SILVER	AG	0.5	52	0	1	3.7	3.1	0	0	0
TIN	SN	0.5	54	45			3.4			2
ZINC	ZN	5	54	54	150	410	410	9	0	0
Polynuclear Aromatic Hydrocarbons (PAH)										
(I)1,2,3-C,D-PYRENE	INDENO	1.4	51	35			600			0
1-METHYLNAPHTHALENE	MENAP1	3.1	54	11						
1-METHYLPHENANTHRENE	MEPHEN1	3.1	50	21						

Chemical Name	Abbreviation	Minimum Detection Limit (MDL)	Frequency of concentration		Sediment Quality Guideline Values			Frequency of reported concentrations exceeded SQG values		
			Reported (detected)	Exceeded MDL	ERL	ERM	AET	> ERL	> ERM	> AET
2,3,5-TRIMETHYLNAPHTHALENE	TRIMETH	3.1	34	3						
2,6-DIMETHYLNAPHTHALENE	DIMETH	3.1	46	8						
2-METHYLNAPHTHALENE	MENAP2	3.1	54	18	70	670	64	0	0	0
ACENAPHTHENE	ACENTHE	1	51	21	16	500	130	1	0	0
ACENAPHTHYLENE	ACENTHY	1	51	25	44	640	71	1	0	0
ANTHRACENE	ANTHRA	0.77	50	37	85.3	1100	280	2	0	1
BENZO(A)ANTHRACENE	BENANTH	1.2	39	37	261	1600	960	2	0	0
BENZO(A)PYRENE	BENAPY	1.8	50	33	430	1600	1100	1	0	0
BENZO(B)FLUORANTHENE	BENZOBFL	2.6	53	36			1800			0
BENZO(G,H,I)PERYLENE	BENZOP	1.4	53	36			670			0
BENZO(K)FLUORANTHENE	BENZOKFL	1.4	53	36			1800			0
BIPHENYL	BIPHENYL	0.8	50	25						
CHRYSENE	CHRYSENE	0.98	49	40	384	2800	950	2	0	0
DIBENZO(A,H)ANTHRACENE	DIBENZ	1.2	48	26	63.4	260	230	1	0	0
DIBENZOTHIOPHENE	DIBENZO	0.7	46	33						
FLUORANTHENE	FLUORANT	0.91	54	45	600	5100	1300	2	0	1
FLUORENE	FLUORENE	1.3	50	32	19	540	120	3	0	0
NAPHTHALENE	NAPH	3.1	54	26	160	2100	230	0	0	0

Chemical Name	Abbreviation	Minimum Detection Limit (MDL)	Frequency of concentration		Sediment Quality Guideline Values			Frequency of reported concentrations exceeded SQG values		
			Reported (detected)	Exceeded MDL	ERL	ERM	AET	> ERL	> ERM	> AET
PYRENE	PYRENE	0.84	54	44	665	2600	2400	1	0	0
Total PAHs	T_PAHs				4022	44792		2	0	
Polychlorinated Biphenyls (PCB)										
PCB 101	PCB101	0.53	53	19						
PCB 105	PCB105	0.56	40	1						
PCB 118/108/149	PCB118	0.55	43	15						
PCB 126	PCB126	0.56	1	0						
PCB 128	PCB128	0.39	33	1						
PCB 138	PCB138	0.69	27	11						
PCB 153	PCB153	0.32	53	28						
PCB 170	PCB170	0.56	27	0						
PCB 18	PCB18	0.87	10	0						
PCB 180	PCB180	0.44	44	4						
PCB 187/182/159	PCB187	0.4	43	10						
PCB 195	PCB195	0.5	15	0						
PCB 206	PCB206	0.58	44	0						
PCB 209	PCB209	0.53	51	2						
PCB 28	PCB28	0.53	47	18						
PCB 44	PCB44	0.55	18	11						
PCB 52	PCB52	0.56	29	3						
PCB 66	PCB66	0.45	34	6						
PCB 77	PCB77	0.71	1	0						
PCB 8	PCB8	0.39	4	2						
Total PCBs	**T_PCB**				**22.7**	**180**	**130**	**0**	**0**	**0**

Chemical Name	Abbreviation	Minimum Detection Limit (MDL)	Frequency of concentration		Sediment Quality Guideline Values			Frequency of reported concentrations exceeded SQG values		
			Reported (detected)	Exceeded MDL	ERL	ERM	AET	> ERL	> ERM	> AET
Pesticides										
ALDRIN	ALDRIN	0.46	1	0			9.5			0
ALPHA-CHLORDANE	ALPHACHL	0.43	33	9						
ALPHA-ENDOSULFAN	ENDOSUL1	0.71	2	1						
BETA-ENDOSULFAN	ENDOSUL2	0.71	2	2						
DIELDRIN	DIELDRIN	0.43	40	5			1.9			0
ENDOSULFAN SULFATE	ENDOSUL	0.2	41	7						
ENDRIN	ENDRIN	0.43	0	0						
HEPTACHLOR	HEPTACHL	0.43	1	0			0.3			0
HEPTACHLOR-EPOXIDE	HEPTAEPO	0.43	25	1						
HEXACHLOROBENZENE	HEXACHL	0.21	6	1			6			0
LINDANE (GAMMA-BHC)	LINDANE	0.31	14	0			4.8			0
MIREX	MIREX	0.21	1	0						
TOXAPHENE	TOXAPHEN	28	0	0						
TRANS-NONACHLOR	TNONCHL	0.31	35	11						
DDT and Metabolites										
O,P'DDD	OPDDD	0.43	36	13						
O,P'DDE	OPDDE	0.71	1	0						
O,P'DDT	OPDDT	0.71	13	3						
P,P'DDD	PPDDD	1	41	4			16			0
P,P'DDE	PPDDE	0.71	52	24			9			0
P,P'DDT	PPDDT	1	27	1			12			0

Chemical Name	Abbreviation	Minimum Detection Limit (MDL)	Frequency of concentration		Sediment Quality Guideline Values			Frequency of reported concentrations exceeded SQG values		
			Reported (detected)	Exceeded MDL	ERL	ERM	AET	> ERL	> ERM	> AET
Total DDTs	Tot-DDT				1.58	46.1	11	23	0	1

Table 5.2.3 Correlation matrix for sediment texture and contaminant data based on 54 sediment samples collected for MCBP in 2000. The correlations were done using Pearson product-moment technique. Correlation analysis was conducted pairwise to include sample with missing parameter values. Values listed are Pearson correlation coefficients (r) (top value), sample size (in parenthesis), and *p*-value (in italic).

-		Water	siltclay	TOC	AL	SB	AS	CD	CR	CU
Water	***Correlation***		0.8644	0.8403	0.7735	0.8459	0.796	0.7989	0.8224	0.7856
	(Sample Size)		(54)	(50)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
siltclay	***Correlation***	0.8644		0.7295	0.9341	0.7925	0.9288	0.5931	0.9769	0.6742
	(Sample Size)	(54)		(50)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*		*0*	*0*	*0*	*0*	*0*	*0*	*0*
TOC	***Correlation***	0.8403	0.7295		0.6143	0.7201	0.6437	0.8535	0.7106	0.6859
	(Sample Size)	(50)	(50)		(50)	(50)	(50)	(50)	(50)	(50)
	PValue	*0*	*0*		*0*	*0*	*0*	*0*	*0*	*0*
AL	***Correlation***	0.7735	0.9341	0.6143		0.7604	0.8792	0.4711	0.9499	0.572
	(Sample Size)	(54)	(54)	(50)		(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0*		*0*	*0*	*0.0003*	*0*	*0*
SB	***Correlation***	0.8459	0.7925	0.7201	0.7604		0.8043	0.7206	0.7975	0.7674
	(Sample Size)	(54)	(54)	(50)	(54)		(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0*	*0*		*0*	*0*	*0*	*0*
AS	***Correlation***	0.796	0.9288	0.6437	0.8792	0.8043		0.5493	0.9381	0.7261
	(Sample Size)	(54)	(54)	(50)	(54)	(54)		(54)	(54)	(54)
	PValue	*0*	*0*	*0*	*0*	*0*		*0*	*0*	*0*
CD	***Correlation***	0.7989	0.5931	0.8535	0.4711	0.7206	0.5493		0.5621	0.7849
	(Sample Size)	(54)	(54)	(50)	(54)	(54)	(54)		(54)	(54)
	PValue	*0*	*0*	*0*	*0.0003*	*0*	*0*		*0*	*0*
CR	***Correlation***	0.8224	0.9769	0.7106	0.9499	0.7975	0.9381	0.5621		0.6657
	(Sample Size)	(54)	(54)	(50)	(54)	(54)	(54)	(54)		(54)
	PValue	*0*	*0*	*0*	*0*	*0*	*0*	*0*		*0*
CU	***Correlation***	0.7856	0.6742	0.6859	0.572	0.7674	0.7261	0.7849	0.6657	
	(Sample Size)	(54)	(54)	(50)	(54)	(54)	(54)	(54)	(54)	
	PValue	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	
FE	***Correlation***	0.8772	0.9832	0.725	0.952	0.8167	0.9432	0.6221	0.9745	0.6934
	(Sample Size)	(54)	(54)	(50)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
PB	***Correlation***	0.9481	0.7819	0.8481	0.691	0.836	0.7193	0.8608	0.7414	0.8087
	(Sample Size)	(54)	(54)	(50)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
MN	***Correlation***	0.5584	0.8093	0.3901	0.8892	0.5776	0.8136	0.2374	0.836	0.4235
	(Sample Size)	(54)	(54)	(50)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0.0051*	*0*	*0*	*0*	*0.0839*	*0*	*0.0014*
HG	***Correlation***	0.8984	0.799	0.8303	0.7027	0.8668	0.7736	0.8703	0.7866	0.8937
	(Sample Size)	(54)	(54)	(50)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
NI	***Correlation***	0.8632	0.9804	0.6839	0.9526	0.8108	0.9408	0.5914	0.9744	0.701

-		Water	siltclay	TOC	AL	SB	AS	CD	CR	CU
	(Sample Size)	(54)	(54)	(50)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
SE	*Correlation*	0.9346	0.7644	0.8759	0.6417	0.8127	0.7141	0.9245	0.7156	0.8257
	(Sample Size)	(54)	(54)	(50)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
AG	*Correlation*	0.6834	0.8078	0.5087	0.8725	0.67	0.7604	0.4445	0.8176	0.5704
	(Sample Size)	(54)	(54)	(50)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0.0002*	*0*	*0*	*0*	*0.0008*	*0*	*0*
SN	*Correlation*	0.9304	0.915	0.8196	0.8367	0.8889	0.8711	0.7942	0.9053	0.8417
	(Sample Size)	(54)	(54)	(50)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
ZN	*Correlation*	0.889	0.7653	0.7966	0.6493	0.7823	0.7277	0.9046	0.7219	0.8413
	(Sample Size)	(54)	(54)	(50)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
T_PAH	*Correlation*	0.3271	0.0885	0.3168	0.0305	0.2914	0.1122	0.256	0.096	0.4703
	(Sample Size)	(54)	(54)	(50)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0.0158*	*0.5245*	*0.025*	*0.8267*	*0.0326*	*0.4193*	*0.0617*	*0.4898*	*0.0003*
T_PCB	*Correlation*	0.7587	0.5548	0.7263	0.4219	0.71	0.5275	0.902	0.5076	0.8469
	(Sample Size)	(54)	(54)	(50)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0*	*0.0015*	*0*	*0*	*0*	*0.0001*	*0*
T_DDTs	*Correlation*	0.7275	0.4185	0.7315	0.2763	0.6506	0.3862	0.8372	0.3549	0.7307
	(Sample Size)	(54)	(54)	(50)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0.0016*	*0*	*0.0431*	*0*	*0.0039*	*0*	*0.0085*	*0*

Table 5.2.3 (cont.). Correlation matrix for sediment texture and contaminant data based on 54 sediment samples collected for MCBP in 2000. The correlations were done using Pearson product-moment technique. Correlation analysis was conducted pairwise to include sample with missing parameter values. Values listed are Pearson correlation coefficients (r) (top value), sample size (in parenthesis), and *p*-value (in italic).

-		FE	PB	MN	HG	NI	SE	AG	SN	ZN
Water	*Correlation*	0.8772	0.9481	0.5584	0.8984	0.8632	0.9346	0.6834	0.9304	0.889
	(Sample Size)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
siltclay	*Correlation*	0.9832	0.7819	0.8093	0.799	0.9804	0.7644	0.8078	0.915	0.7653
	(Sample Size)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
TOC	*Correlation*	0.725	0.8481	0.3901	0.8303	0.6839	0.8759	0.5087	0.8196	0.7966
	(Sample Size)	(50)	(50)	(50)	(50)	(50)	(50)	(50)	(50)	(50)
	PValue	*0*	*0*	*0.0051*	*0*	*0*	*0*	*0.0002*	*0*	*0*
AL	*Correlation*	0.952	0.691	0.8892	0.7027	0.9526	0.6417	0.8725	0.8367	0.6493
	(Sample Size)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
SB	*Correlation*	0.8167	0.836	0.5776	0.8668	0.8108	0.8127	0.67	0.8889	0.7823
	(Sample Size)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
AS	*Correlation*	0.9432	0.7193	0.8136	0.7736	0.9408	0.7141	0.7604	0.8711	0.7277
	(Sample Size)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

-		FE	PB	MN	HG	NI	SE	AG	SN	ZN
CD	***Correlation***	0.6221	0.8608	0.2374	0.8703	0.5914	0.9245	0.4445	0.7942	0.9046
	(Sample Size)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0.0839*	*0*	*0*	*0*	*0.0008*	*0*	*0*
CR	***Correlation***	0.9745	0.7414	0.836	0.7866	0.9744	0.7156	0.8176	0.9053	0.7219
	(Sample Size)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
CU	***Correlation***	0.6934	0.8087	0.4235	0.8937	0.701	0.8257	0.5704	0.8417	0.8413
	(Sample Size)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0.0014*	*0*	*0*	*0*	*0*	*0*	*0*
FE	***Correlation***		0.7977	0.8399	0.8091	0.9919	0.7813	0.8318	0.9226	0.7876
	(Sample Size)		(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
PB	***Correlation***	0.7977		0.4654	0.9083	0.7807	0.9226	0.6357	0.9255	0.9268
	(Sample Size)	(54)		(54)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*		*0.0004*	*0*	*0*	*0*	*0*	*0*	*0*
MN	***Correlation***	0.8399	0.4654		0.4844	0.8407	0.399	0.8389	0.659	0.471
	(Sample Size)	(54)	(54)		(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0.0004*		*0.0002*	*0*	*0.0028*	*0*	*0*	*0.0003*
HG	***Correlation***	0.8091	0.9083	0.4844		0.8056	0.9176	0.666	0.9513	0.9016
	(Sample Size)	(54)	(54)	(54)		(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0.0002*		*0*	*0*	*0*	*0*	*0*
NI	***Correlation***	0.9919	0.7807	0.8407	0.8056		0.7609	0.8317	0.9178	0.7727
	(Sample Size)	(54)	(54)	(54)	(54)		(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0*	*0*		*0*	*0*	*0*	*0*
SE	***Correlation***	0.7813	0.9226	0.399	0.9176	0.7609		0.5505	0.8906	0.9113
	(Sample Size)	(54)	(54)	(54)	(54)	(54)		(54)	(54)	(54)
	PValue	*0*	*0*	*0.0028*	*0*	*0*		*0*	*0*	*0*
AG	***Correlation***	0.8318	0.6357	0.8389	0.666	0.8317	0.5505		0.7762	0.6355
	(Sample Size)	(54)	(54)	(54)	(54)	(54)	(54)		(54)	(54)
	PValue	*0*	*0*	*0*	*0*	*0*	*0*		*0*	*0*
SN	***Correlation***	0.9226	0.9255	0.659	0.9513	0.9178	0.8906	0.7762		0.8986
	(Sample Size)	(54)	(54)	(54)	(54)	(54)	(54)	(54)		(54)
	PValue	*0*	*0*	*0*	*0*	*0*	*0*	*0*		*0*
ZN	***Correlation***	0.7876	0.9268	0.471	0.9016	0.7727	0.9113	0.6355	0.8986	
	(Sample Size)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	
	PValue	*0*	*0*	*0.0003*	*0*	*0*	*0*	*0*	*0*	
T_PAH	***Correlation***	0.0832	0.4286	0.0707	0.3455	0.0939	0.254	0.0445	0.2756	0.2172
	(Sample Size)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0.5495*	*0.0012*	*0.6112*	*0.0105*	*0.4995*	*0.0638*	*0.7491*	*0.0437*	*0.1147*
T_PCB	***Correlation***	0.5686	0.8422	0.2287	0.8617	0.5504	0.8342	0.4737	0.7802	0.8734
	(Sample Size)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0*	*0*	*0.0962*	*0*	*0*	*0*	*0.0003*	*0*	*0*
T_DDTs	***Correlation***	0.4253	0.8226	0.0328	0.763	0.3983	0.793	0.2911	0.6676	0.7486
	(Sample Size)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)
	PValue	*0.0013*	*0*	*0.8136*	*0*	*0.0029*	*0*	*0.0327*	*0*	*0*

Table 5.2.4**.** Summary of physical and chemical data for sediment samples collected in 2000 for MCBP. Clay content was calculated as % Clay=0.308871(% Siltclay)+0.055768(%Water). Excess total carbon (TOC) was calculated as the difference between measured TOC and predicted TOC, where predicted TOC= 0.0448 * %Clay-0.079. Both equations are based on sediment data from Wells and others (1999). Frequency of reported contaminant concentrations exceeding mean detection limit (MDL), ERL, ERM and AET limits, and AET Quotient are listed for each sample.

STA	BASIN	% Water	Clay	% TOC	Excess TOC	Number of sediment contaminants: Metals Total	Metals > MDL	Organic Total	Organic > MDL	Number of sediment contaminants exceeding threshold values: ERL	ERM	AET	Mean AET Quotient
MD-CB-01	W.OC Harbor	64.00	27.87	1.64	0.39	15	12	49	39	**12**	**0**	**2**	**0.34**
MD-CB-02	Sinepuxent	23.53	4.15	0.31	0.12	15	10	36	3	**0**	**0**	**0**	**0.05**
MD-CB-03	NewportBay	20.50	2.54	0.18	0.07	12	6	27	1	**0**	**0**	**0**	**0.02**
MD-CB-04	NewportBay	69.67	31.95			15	12	43	21	**3**	**0**	**1**	**0.14**
MD-CB-05	Chincoteague	53.72	31.14			15	12	44	16	**2**	**0**	**2**	**0.13**
MD-CB-06	Chincoteague	28.16	6.08	0.26	-0.01	15	8	37	2	**0**	**0**	**0**	**0.05**
MD-CB-07	JohnsonBay	56.18	30.63	1.4	0.03	15	12	40	12	**2**	**0**	**1**	**0.12**
MD-CB-08	ChincoteagueBay_VA	47.48	23.66	1.33	0.27	15	12	42	13	**2**	**0**	**1**	**0.11**
MD-CB-09	ChincoteagueBay_VA	45.39	20.52	0.88	-0.04	15	12	40	9	**1**	**0**	**1**	**0.10**
MD-CB-10	ChincoteagueBay_VA	54.15	27.86	1.23	-0.02	15	12	44	11	**2**	**0**	**1**	**0.12**
MD-CB-11	ChincoteagueBay_VA	18.64	1.49	0.06	-0.01	13	7	27	3	**0**	**0**	**0**	**0.04**
MD-CB-12	ChincoteagueBay_VA	18.38	1.78	0.32	0.24	11	7	30	1	**0**	**0**	**0**	**0.04**
MD-CB-13	ChincoteagueBay_VA	17.09	1.83	0.13	0.05	12	6	27	1	**0**	**0**	**0**	**0.03**
MD-CB-14	JohnsonBay	46.31	23.23	1.55	0.51	15	12	40	10	**1**	**0**	**1**	**0.10**
MD-CB-15	Chincoteague	22.69	4.05	0.12	-0.06	14	8	32	3	**0**	**0**	**0**	**0.04**
MD-CB-16	Sinepuxent	38.66	14.09	0.7	0.07	15	11	41	14	**0**	**0**	**1**	**0.08**
MD-CB-17	Sinepuxent	17.75	1.29	0.13	0.07	11	5	19	2	**1**	**0**	**0**	**0.03**
MD-CB-18	Sinepuxent	12.97	0.97	0.08	0.04	10	5	23	0	**0**	**0**	**0**	**0.01**
MD-CB-19	BishipvilleProng	73.91	25.55	3.25	2.11	15	13	49	35	**4**	**0**	**0**	**0.20**
MD-CB-20	BishipvilleProng	42.99	4.61	0.48	0.27	15	10	44	24	**2**	**0**	**0**	**0.08**
MD-CB-21	HerringCreek	76.11	32.07	4.69	3.25	15	13	46	32	**5**	**0**	**1**	**0.22**
MD-CB-22	ShingleLdg	76.51	32.95			15	13	44	30	**5**	**0**	**2**	**0.19**
MD-CB-23	ShingleLdg	79.16	33.03	6.6	5.12	15	13	47	31	**5**	**0**	**1**	**0.20**
MD-CB-24	TurvilleCreek	68.17	28.47	0.55	-0.73	15	12	49	32	**3**	**0**	**1**	**0.18**
MD-CB-25	TurvilleCreek	41.20	9.00	0.23	-0.17	15	11	44	23	**1**	**0**	**0**	**0.11**
MD-CB-26	BishipvilleProng	83.38	30.45	5.69	4.33	15	13	49	40	**5**	**0**	**2**	**0.24**
MD-CB-27	St.MartinR	58.27	32.06	3	1.56	15	12	47	26	**3**	**0**	**2**	**0.17**

						Number of sediment contaminants				Number of sediment contaminants exceeding threshold values			Mean AET Quotient
						Metals		Organic					
STA	**BASIN**	**% Water**	**Clay**	**% TOC**	**Excess TOC**	**Total**	**> MDL**	**Total**	**> MDL**	**ERL**	**ERM**	**AET**	
MD-CB-28	St.MartinR	57.14	32.76	2.88	1.41	15	12	47	25	**3**	**0**	**2**	**0.16**
MD-CB-29	St.MartinR	65.91	33.63	4.97	3.46	15	13	46	30	**4**	**0**	**3**	**0.19**
MD-CB-30	St.MartinR	73.18	32.13	6.52	5.08	15	13	48	34	**5**	**0**	**2**	**0.21**
MD-CB-31	BishipvilleProng	19.89	1.56	0.06		10	7	21	0	**0**	**0**	**0**	**0.03**
MD-CB-32	AyersCreek	26.62	2.29	0.33	0.23	13	5	43	22	**1**	**0**	**0**	**0.07**
MD-CB-33	NewportCreek	57.36	12.59	4.09	3.53	15	11	44	28	**10**	**0**	**1**	**0.29**
MD-CB-34	NewportCreek	75.33	15.92	3.28	2.57	15	11	35	28	**3**	**0**	**0**	**0.16**
MD-CB-35	TrappeCreek	21.30	2.03	0.19	0.10	13	8	46	11	**0**	**0**	**0**	**0.04**
MD-CB-36	Chincoteague	37.72	13.10	0.69	0.10	15	10	42	9	**0**	**0**	**1**	**0.08**
MD-CB-37	NewportBay	52.08	32.10	1.71	0.27	15	12	45	17	**2**	**0**	**1**	**0.13**
MD-CB-38	NewportBay	56.74	31.90	2.29	0.86	15	12	44	14	**1**	**0**	**1**	**0.12**
MD-CB-39	Isle of Wight	14.28	1.04	0.05	0.00	9	5	11	0	**0**	**0**	**0**	**0.01**
MD-CB-40	Isle of Wight	16.01	1.26	0.09	0.03	12	6	15	0	**0**	**0**	**0**	**0.02**
MD-CB-41	Isle of Wight	43.85	20.04	3.72	2.82	15	12	48	17	**0**	**0**	**1**	**0.11**
MD-CB-42	Isle of Wight	21.85	4.10	0.09	-0.09	14	7	39	7	**0**	**0**	**0**	**0.04**
MD-CB-43	Assawoman	45.90	24.69	1.55	0.44	15	12	47	19	**1**	**0**	**1**	**0.12**
MD-CB-44	Greys Creek	52.85	32.94	3.2	1.72	15	12	43	23	**3**	**0**	**2**	**0.17**
MD-CB-45	Assawoman	37.28	28.86			15	12	45	19	**2**	**0**	**1**	**0.13**
MD-CB-46	TurvilleCreek	64.11	29.76	2.73	1.40	15	12	46	22	**2**	**0**	**2**	**0.14**
MD-CB-47	ManklinCreek	28.22	6.58	0.25	-0.04	15	10	42	7	**0**	**0**	**0**	**0.04**
MD-CB-48	Greys Creek	21.29	3.66	0.25	0.09	15	7	47	26	**1**	**0**	**0**	**0.06**
MD-CB-49	Roys Creek	65.66	29.39	3.77	2.45	15	12	42	26	**3**	**0**	**2**	**0.17**
MD-CB-50	The Ditch	19.95	2.35	0.16	0.05	11	5	35	2	**0**	**0**	**0**	**0.02**
MD-CB-51	Chincoteague	31.66	8.21	0.22	-0.15	15	9	40	2	**0**	**0**	**1**	**0.06**
MD-CB-52	Chincoteague	21.75	3.33	0.22	0.07	12	6	28	0	**0**	**0**	**0**	**0.03**
MD-CB-53	Chincoteague	55.45	30.23	1.26	-0.09	15	12	46	16	**1**	**0**	**1**	**0.12**
MD-CB-54	Chincoteague	29.82	9.42	0.29	-0.13	15	9	40	3	**0**	**0**	**1**	**0.07**